Energy Requirements for a Digital Society

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FY 2001 Energy Storage System Program Peer Review

November 15, 2001

Project Objective and Approach

Objective: Assess needs and roles for OPT technologies as U.S. evolves toward a digital economy and society

Approach:

- **Identify key ICT drivers and likely impacts**

  $\Rightarrow$ **ICT= Information & Communication Technology**

- **Develop 20-year scenarios with alternative paths of ICT development and use**
- **Evaluate scenario implications for electricity requirements and characteristics**
- **Assess implications for OPT technologies and programs**

Why Focus on Hard-to-Predict Long Term Developments?

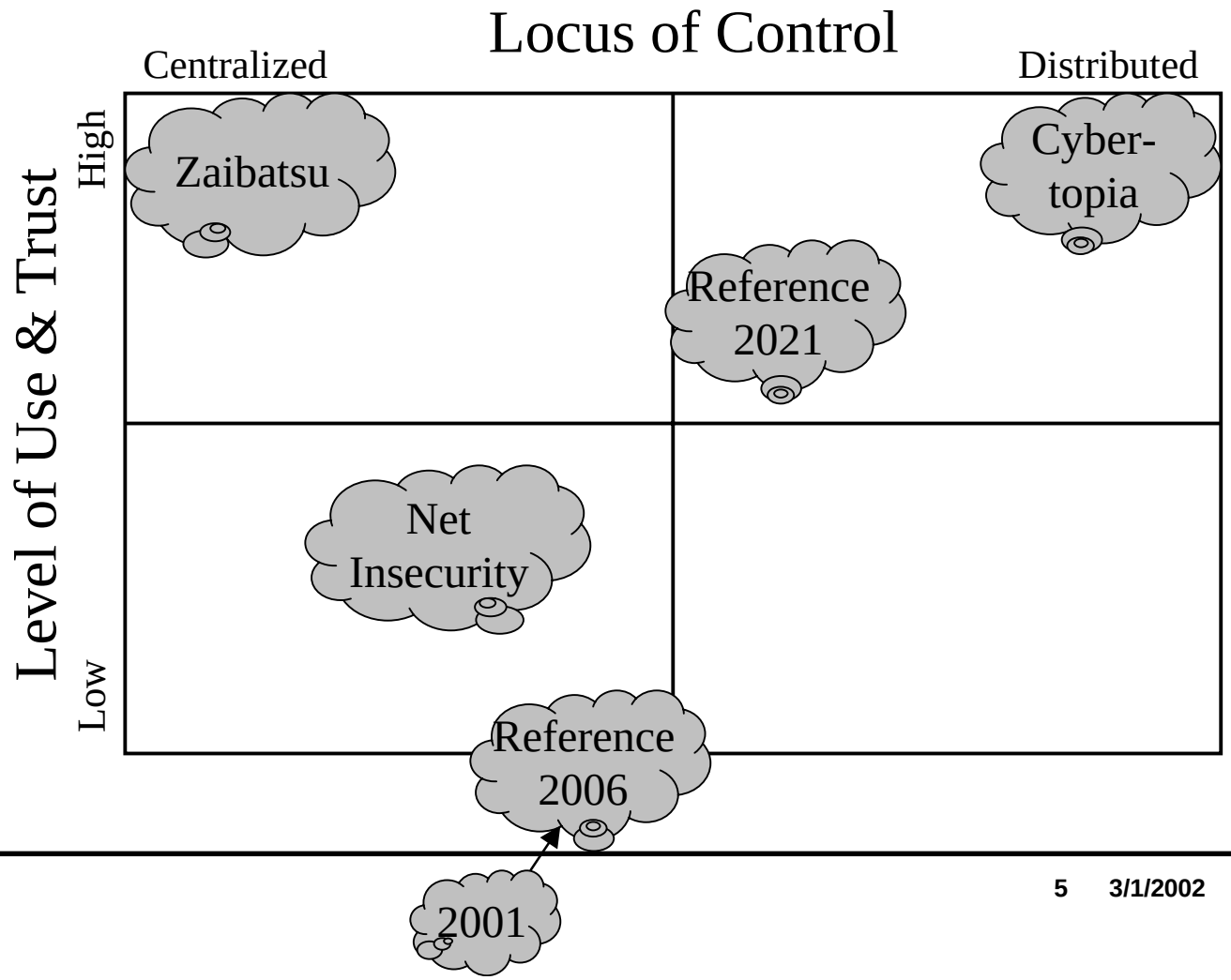
- **This is not a 20-year forecasting exercise**
- **Scenarios depict ICT drivers of electricity use and the uncertainties surrounding them**
- **Scenarios can reveal mismatches between ICT-driven needs and energy technology availability**
- **Scenarios can inform R&D decisions and suggest hedging and shaping strategies**

Scenarios Focused on Two ICT Drivers

We selected these dimensions:

1. **Level of ICT use and trust**
   - **Use more important than technology**
   - **Use correlated with trust and confidence**
2. **Centralized or distributed control**
   - **Important both for ICT and electricity systems**
   - **Choices lead to different evolutionary paths**

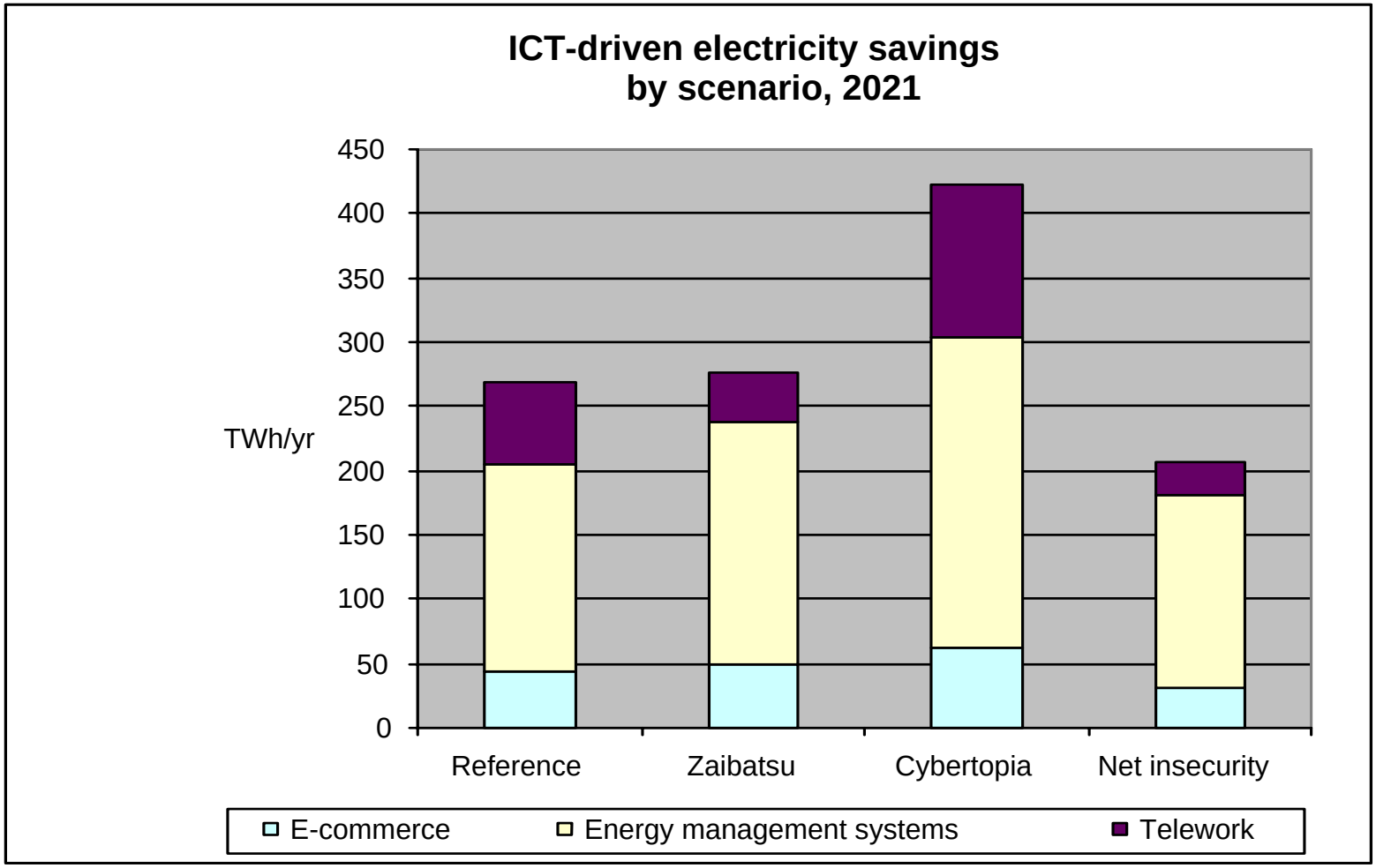
Four ICT Scenarios Through 2021



ICT Affects Electricity Use in Three Ways

1. **Electricity used by ICT devices**
2. **ICT contributions to energy efficiency and energy management**
3. **ICT-related societal changes**
   - **e.g., telework, e-commerce, videoconferencing**
   - **Energy tradeoffs: telework vs. home office**
   - **These are the most important changes in the long run and the most difficult to assess analytically**

ICT-Related Electricity Savings Vary Among 2021 Scenarios



Electricity Supply Issues Raised By ICT Scenarios

- **Assuring power quality for very large numbers of digital devices**
- **Using ICT to improve grid reliability and operations**
- **Using ICT to support distributed generation and storage**
- **Addressing vulnerabilities of ICT and electricity infrastructures**

Assuring Power Quality for Ubiquitous Digital Devices

- **Findings/Observations from Scenarios**
  - **Storage/conditioning feasible at several levels: chip, device, plug, building, "power park"**
  - **Industry restructuring blurs responsibility for quality**
  - **Mfgrs may under-invest in conditioning to keep costs down**
  - **Industry R&D may not meet growing needs for quality**
- **Implications for OPT**
  - **Include power quality in program goals and plans?**
  - **Increased R&D funding for "quality"-related applications: storage, power electronics, harmonic filters, etc.**
  - **Analysis, particularly of system-wide power quality issues**
  - **Inform stakeholders about quality issues, technologies**

Using ICT to Improve Grid Reliability and Operations

- **Findings/Observations from Scenarios**
  - **Even decentralized scenarios need a robust grid**
  - **ICT developments essential for T&D monitoring and control**
  - **Unclear whether industry R&D and structure will provide grid capacity and reliability needed in *Reference* and *Zaibatsu* cases**
- **Implications for OPT**
  - **Need for analysis of system-wide T&D issues such as**
    - **will industry fund needed improvements in T&D reliability?**
    - **will ICTs for adv T&D techs come on line quickly enough?**
    - **are greater T&D margins needed to support competition?**
  - **Analysis may suggest increased OPT R&D funding for T&D**

Using ICT to Support Distributed Generation and Storage

- **Findings/Observations from Scenarios**
  - **Storage increasingly will be integrated with DG**
  - **Technical standards for large DR deployment/interconnection are essential**
  - **Many factors limiting DR growth are non-technical**
  - **ICT will support DR integration and control under all scenarios**
- **Implications for OPT**
  - **Increased R&D funding for DG and storage**
  - **Support DR interconnection standards development and demonstration/verification**
  - **Analysis of regulations/policies for DR dispatch and pricing**
  - **Inform stakeholders about DR technologies, issues**

Addressing Vulnerabilities of Power and ICT Infrastructures

- **Findings/Observations from Scenarios**
  - **While ICT supports both centralized and decentralized scenarios, decentralization adds flexibility and resilience**
  - **“Self-healing” systems are an important goal whose feasibility, cost and timing remain unclear**
  - **Unclear whether Internet will be secure enough for essential communication and control links**
- **Implications for OPT**
  - **View DR as strategy to increase infrastructure robustness**
  - **Increased R&D on ICTs for grid and DR: monitoring, decision-making, control for dynamic supply and demand response**
  - **Analysis of infrastructure efficiency/robustness tradeoffs**

Principal Findings on ICT-Driven Electricity Use by 2021

- **Residential electricity use larger than EIA's estimate; primarily due to more home offices, home networks and digital TV**
  - **home networks generally increase kwh used, but reduce peak loads and save other fuels**
- **Commercial and industrial use below EIA estimates, primarily due to EMS, telework and e-commerce**
  - **telework and e-commerce cut kwh in commercial and industrial sectors while raising use at home**
- **Total electricity use 2-3% lower than EIA estimate**
  - **ICT-driven savings differ widely among scenarios**

2021 Reference Scenario

2001-2006 trends extended and/or modified:

- **Moore's Law slows after 2015 for computing and storage, but not for optical bandwidth**
- **Smart embedded devices, voice control, complex software agents, biometric ID, MEMS in general use**
- **Relatively high use of and confidence in the Net**
- **Balance between centralized and distributed control, although more distributed than in 2006**
- **ICT problems and issues persist, but U.S. society has achieved generally workable solutions**

“ Zaibatsu” 2021

Higher ICT use, more centralized control

- Large multinational corporations (MNCs) own ICT infrastructure and dominate e-commerce
- Emphasis on wired over wireless infrastructure
- Most population, GDP growth in cities and suburbs
- Investment in intelligent transportation systems eases commuting, results in less telework
- Tight security, harsh laws against cybercrime
- Very little privacy, but accepted by 90% of public
- More emphasis on grid, somewhat less on DR

“Cybertopia” 2021

Higher ICT use, distributed control

- ICT infrastructure and Net services operated by mix of large and small enterprises
- Emphasis on wireless over wired infrastructure
- More growth in small towns and rural areas
- More telework, distance learning, telemedicine
- More substitution of e-commerce for store visits
- Very large deployments of tiny wireless sensors
- Technology keeps Net secure, lowers cybercrime
- More emphasis on DR, somewhat less on grid

“Net Insecurity” 2021

Loss of public trust in Net leads to lower usage

- Public Net peaks around 2012 and then declines due to persistent, unresolved security problems
  - massive identity theft and loss of user data
  - penetration of home LANs, standard firewalls
  - destruction, spoofing of information on public Net
  - viruses, malicious code hard to counter
- Less telework, B2C e-commerce, medical monitoring
- Consumers invest heavily in standalone ICTs, one-way media, home LAN islands unconnected to Net

Comparing the 2021 Scenarios

Item	Reference Scenario	Zaibatsu	Cyber-topia	Net Insecur.
Digital TV hh (%)	95	98	98	99
Adult Net users (%)	92	98	95	80
Households on Net (%)	92	98	95	55
Full/part-time teleworkers (mil)	40	30	60	20
IP-addressable devices (billion)	>3	>3	>10	<1
Big firms using e-commerce (%)	98	99	98	90
Consumers using e-commerce(%)	88	95	93	30
HH with home networks (%)	90	95	95	90
Medical monitoring on Net	yes	more	more	little